Variation in root characteristics, and their association with water uptake and drought tolerance in four peanut cultivars

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Summary. An experiment investigating peanut genotypic variation in uptake of water by roots under droughted conditions was conducted in mini-lysimeters embedded within crop canopies in the field. Although the four genotypes studied used the same amount of water during the treatment period, the mass and length of roots differed substantially, indicating that genotypic differences in root water uptake efficiency may exist in peanut. Above-ground plant water status also differed among genotypes throughout the drying cycles, and was least in the genotype showing the most efficient root water uptake. It was hypothesised that genotypic differences in axial root resistance or osmotic adjustment were responsible for this effect.

Introduction

Peanut genotypes differing in their adaptation to drought have been identified (4). While variation in transpiration efficiency (TE) has been shown to be associated with this drought tolerance capability (4,5), there has been little work to assess the importance of the root system in conferring adaptive advantage under drought conditions. This study reports genotypic variation in root characteristics, and investigates their association with water uptake and dehydration tolerance in four peanut genotypes contrasting in drought susceptibility.

Methods

A field experiment was conducted on Krasnozem soil at the Bjelke-Petersen Research Station, Kingaroy, Queensland, during the 1990-91 season. Cultural and other details of this experiment have been reported previously (5). Briefly, four peanut cultivars (Chico, McCubbin, Shulamit and Tifton-8), selected on the basis of differences in TE characteristics, were grown in mini-lysimeters embedded within crop canopies and located within portable rainout shelters. A drought treatment consisting of two episodes of 25 days duration each, was imposed, with a single watering following the first drying cycle. This treatment was imposed in each mini-lysimeter, and surrounding plot area for each genotype (4 x 30 cm rows of 6.5 m length), soon after flowering (about 4.6 days after planting). There were 4 replicates of each genotype, with two mini-lysimeters located in each replicate.

Water-use from mini-lysimeters was estimated by weighing using an electronic load cell mounted on a tractor driven gantry. Each pot was initially watered up to field capacity (86.0 kg) at the beginning of the treatment period, and again after the first drying cycle (25 days later). The driest mini-lysimeter measured was 77.0 kg (representing the field determined wilting point), which meant there was 9 kg of plant available water. The plant available water content (PAWC) at periods throughout each drying cycle was calculated as the percentage of water remaining above the 77.0 kg lower limit. Water content estimates at 10, 30 and 60 cm intervals were made using gypsum blocks installed into mini-lysimeters (2 replicates only). Readings were made at regular intervals throughout the second drying cycle only.

Leaf relative water content (RWC) was measured at regular intervals throughout the treatment period using the methods discussed previously (I). At the end of the treatment period, the soil from each mini-lysimeter was removed and sectioned into four 20 cm layers so that roots could be measured using methods discussed previously (5). Root length of each interval was measured using an image analysis procedure, and root weight of the same sample measured following weighing after drying at 80?C for 24 h.

Results

There were no significant genotypic differences in the rate or amount of water use over the treatment period, as evidenced by the change in PAWC with time (Fig. I). Total water use over the treatment period averaged 12.5 kg per mini-lysimeter (or 88 mm on an area basis) for the four genotypes.

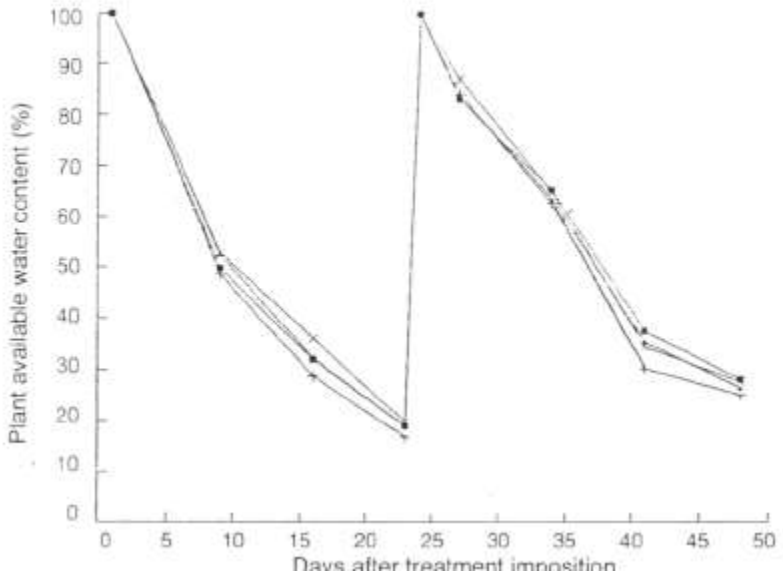

Figure 1. Change in PAWC over time following treatment imposition for four peanut genotypes (Tifton-8 (+), Shulamit (x), McCubbin (•), Chico (N). There were no significant differences between cultivars at any time.

Root weight (RW) and root length density (RLD) declined rapidly from the surface to the base of the mini-lysimeters for all genotypes (Figs 2a,b). There were, however, substantial differences between genotypes, with Tifton-8 having significantly higher RW's and RLD's compared to Chico in the 0-20cm and 20-40cm intervals. The average specific root length (length per unit weight) was similar among genotypes.

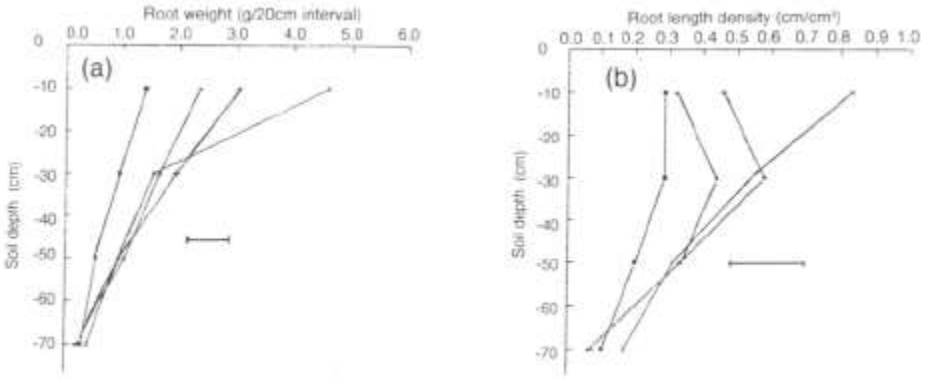

Figure 2. The change in root weight (a) and root length density (b) with soil depth in mini-lysimeters for the four peanut genotypes. Symbols as for Figure 1. Horizontal bars denote l.s.d. (P=0.05).

It was apparent from the water use and root data that genotypic differences in the efficiency of water uptake per unit root length (Reff) may have existed during the treatment period. To quantify this hypothesis, Reff was calculated for water usage during the second drying cycle at depth intervals where gypsum block sensors were located. These calculations assumed that all roots are uniformly active in terms of water uptake over the entire soil profile, and that there were no differences between roots of different genotypes. This is a reasonable assumption as the specific root lengths were similar between genotypes. Table I shows that Reff differed significantly ($P<0.05$) between genotypes at each depth interval, with Chico having an apparent Reff up to 3 times greater than Tifton-8.

Table 1. Uptake of water per unit root length per day for 4 peanut genotypes over the second 20 day drying cycle.

Depth interval (cm)	Reff ($cm^3/m/d$)			
	Chico	McCubbin	Shulamit	Tifton-8
0-20	3.46	3.34	2.27	1.25
20-40	4.10	2.75	1.97	1.95
40-80	4.29	2.63	2.23	1.94
l.s.d. (P=0.05)		2.02		

Plant water status was monitored during the treatment period via leaf RWC measurements (Fig.3). The trend in RWC followed that observed for PAWC, however large genotypic differences were observed after about 10 days following soil replenishment during both drying cycles. Tifton-8, McCubbin and Shulamit maintained significantly ($P<0.05$) higher RWC's compared to Chico late in each drying cycle. The relationship between RWC and PAWC (Fig. 4) indicated that genotypes differed in their sensitivity to soil water deficits, with RWC for Chico declining at substantially higher levels of PAWC than the other 3 genotypes.

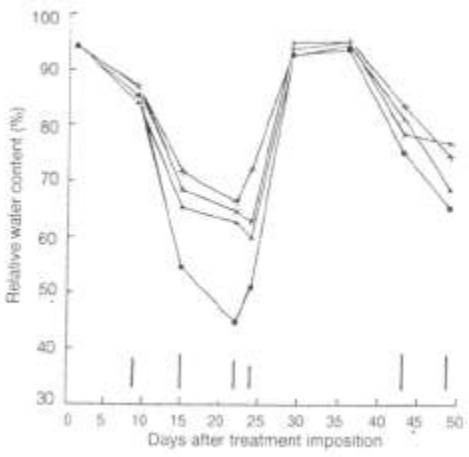

Figure 3. The change in PAWC over time following imposition for 4 peanut genotypes. Symbols as for Figure 1. Vertical bars denote l.s.d. (P=0.05)

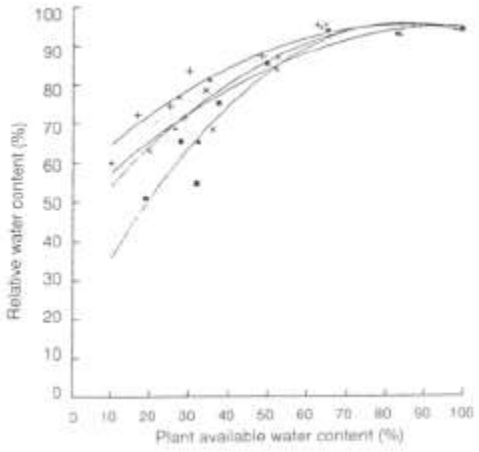

Figure 4. Relationship between RWC and PAWC over the treatment period. Symbols as for Figure 1.

Discussion

This study has shown that although water usage was similar among the four genotypes, the root systems differed substantially in the capture of this water. Indeed, the data in Table I show that Chico was considerably more efficient in taking up water per unit root length throughout the root system when compared to the other genotypes. This response may indicate that genotypes like Tifton-8 may have an excess root length (and biomass) than is required for normal water uptake. If this were the case, it could be argued that genotypes with more "efficient" water uptake capacity might be able to be selected in future breeding programs. If this extra biomass could be re-allocated to the pod component, increased pod yields may be possible under conditions of water limitation. Further research is warranted to investigate this possibility.

When the water status of the above-ground plant is considered, however, it appears that the more extensive root system of genotypes such as Tifton-8 may be necessary to maintain plant hydration. This effect is well illustrated in Figs. I, 3 and 4 where Chico was observed to have significantly lower leaf RWC compared to the other genotypes throughout each drying cycle, despite being at a similar PAWC. It could be argued that Chico's "less dense" root system had higher axial resistance to water uptake. which in turn led to reduced leaf water potential and lowered RWC. Genotypes such as Tifton-8, on the other hand, with a considerably more branched surface root system would have had lower axial resistance. This would enable the maintenance of relatively higher leaf water potential, leaf RWC and presumably other processes such as photosynthesis, despite lowered PAWC.

An alternative hypothesis is that genotypic differences in osmotic adjustment existed, such that the Tifton-8 types were able to maintain positive leaf turgor and hence higher leaf RWC because of active solute accumulation (3). The lack of leaf water and osmotic potential measurements don't allow us to explore this possibility, however genotypic variation in osmotic adjustment has been observed elsewhere in peanut (2).

Whatever mechanism is operating, it is apparent that substantial genotypic differences in dehydration tolerance exist in peanut. These differences also seem to be related to genotypic differences in transpiration efficiency (4,5) and rooting characteristics. Further research seems warranted to investigate the inter-relationships between these traits so that selection criteria can be accurately determined in breeding programs aimed at improving peanut drought tolerance.

Acknowledgements

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